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Plug-in Hybrid Electric Vehicle Environmental Assessment

California Emerging Clean Air Technology Forum

July 9, 2008

Mark Alexander
Manager, Vehicle Systems Analysis

Overview

CO_2 Results

Air Quality Results

Next Steps

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Next Steps

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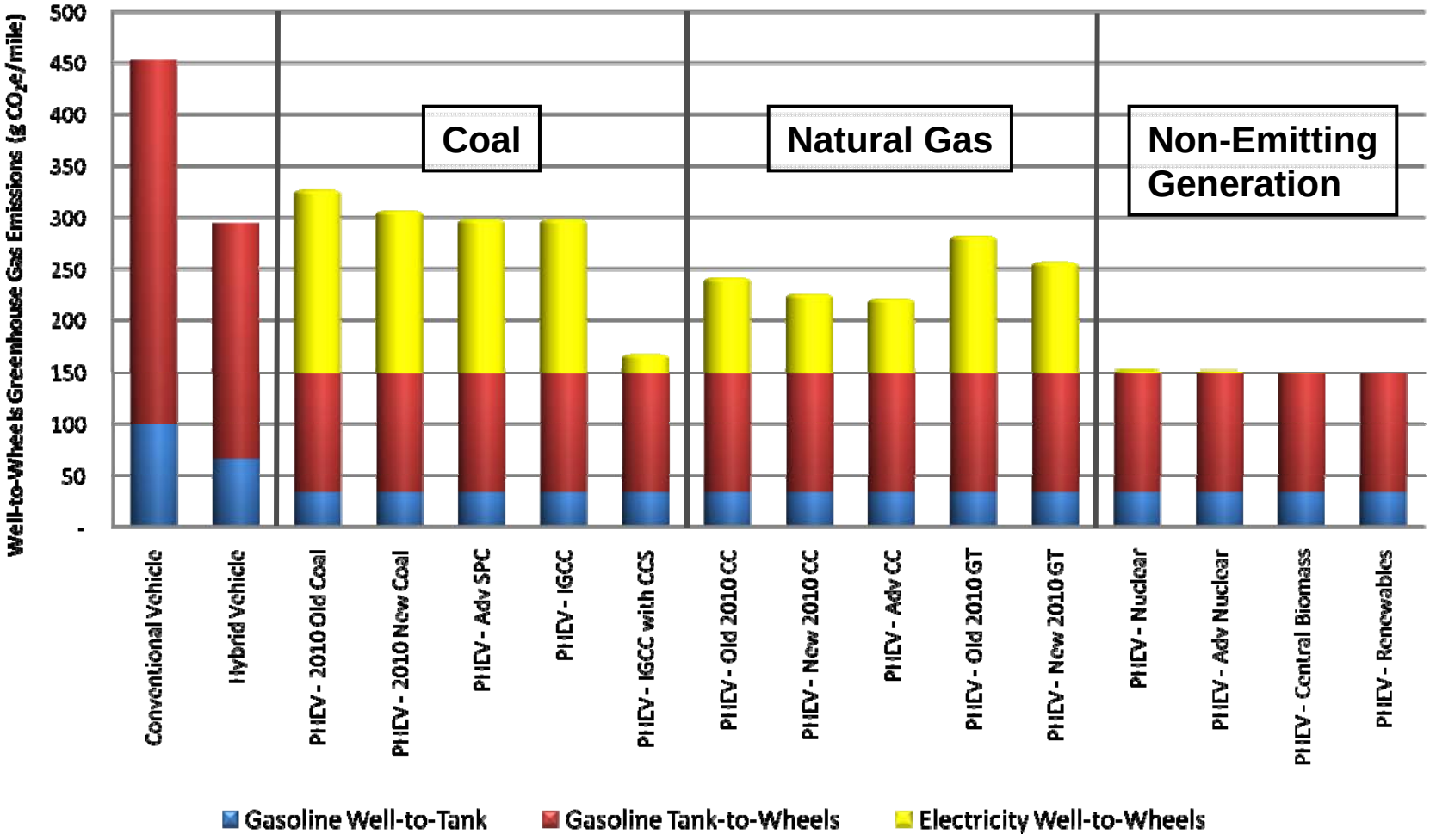
Power Plant-Specific PHEV Emissions in 2010
PHEV 20 – 12,000 Annual Miles



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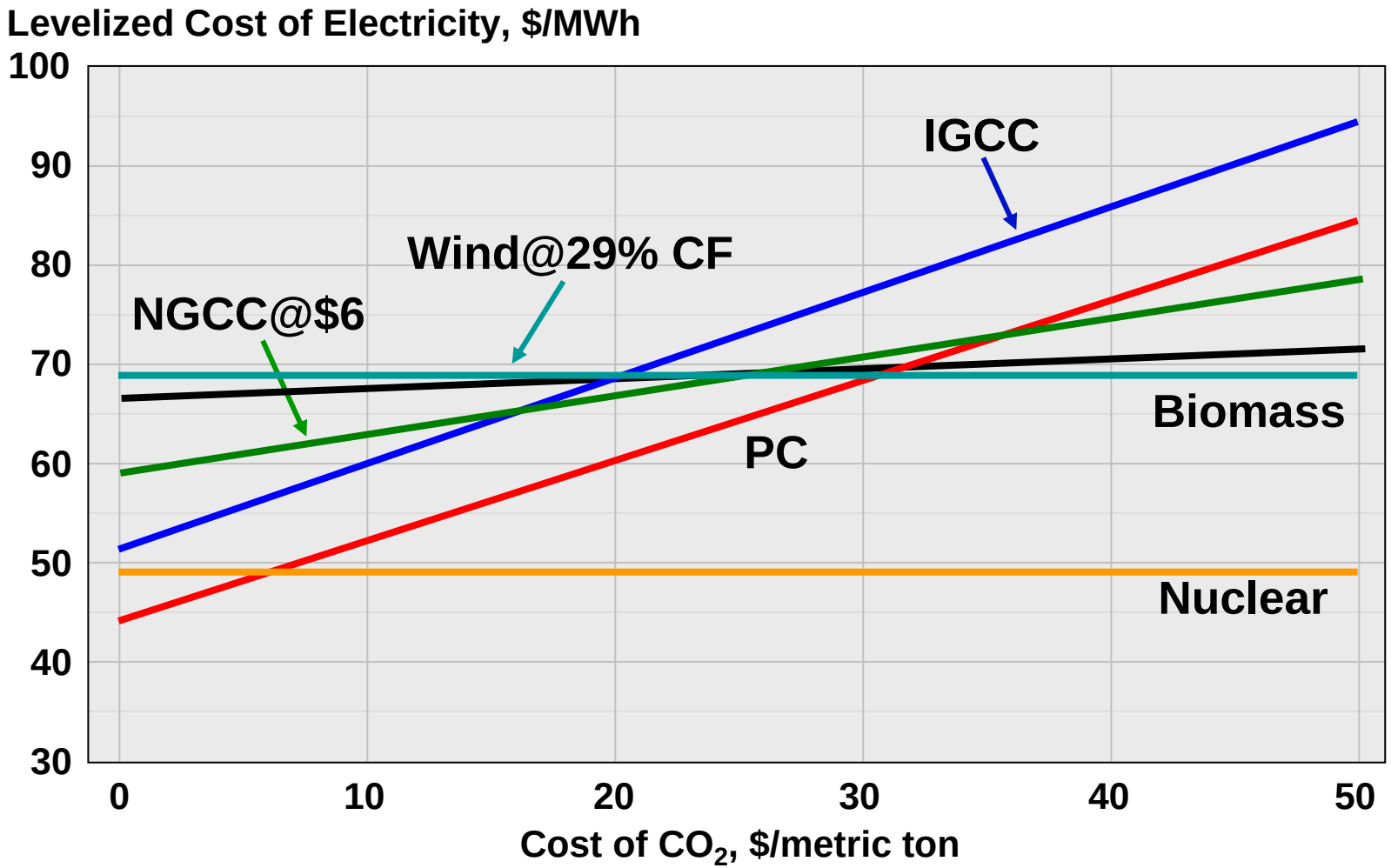
Technologies for New Generation in 2010-2015



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Electric Sector Scenarios

Scenario Definition	High CO_2	Medium CO_2	Low CO_2
Cost of CO_2 Emissions Allowances	Low	Moderate	High
Power Plant Retirements	Slower	Normal	Faster
New Generation Technologies	Unavailable: Coal with CCS New Nuclear New Biomass	Normal Technology Availability and Performance	Available: Retrofit of CCS to existing IGCC and PC plants
	Lower Performance: SCPC, CCNG, GT, Wind, and Solar		Higher Performance: Solar
Annual Electricity Demand Growth	1.56% per year on average	1.56% per year on average	2010 - 2025: 0.45% 2025 - 2050: None

SCPC – Supercritical Pulverized Coal CCNG – Combined Cycle Natural Gas
GT – Gas Turbine (natural gas) CCS – Carbon Capture and Storage

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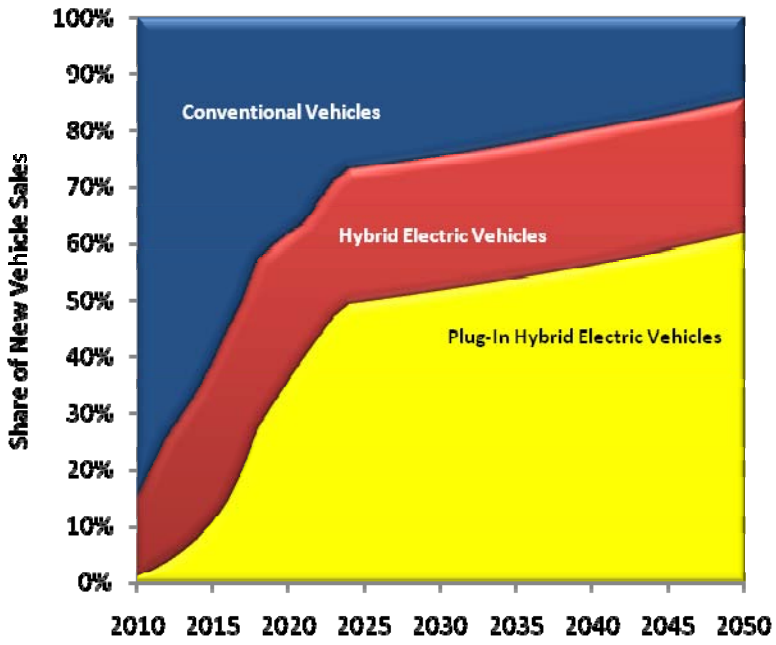
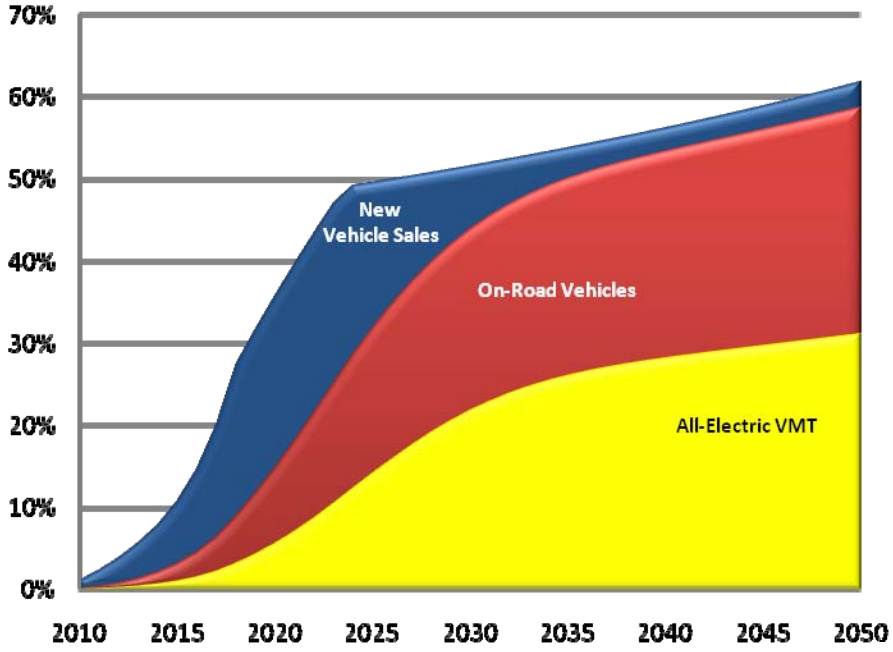
PHEV Medium Scenario

- Low, Medium, High PHEV market penetration scenarios
- Corresponds to 20%, 60%, and 80% peak market share
- New vehicles take time to penetrate nationwide fleet



New Vehicle Market Share: Medium PHEV Scenario



Growth of PHEVs and eVMT in Nationwide Fleet

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Overview

CO_2 Results

Air Quality Results

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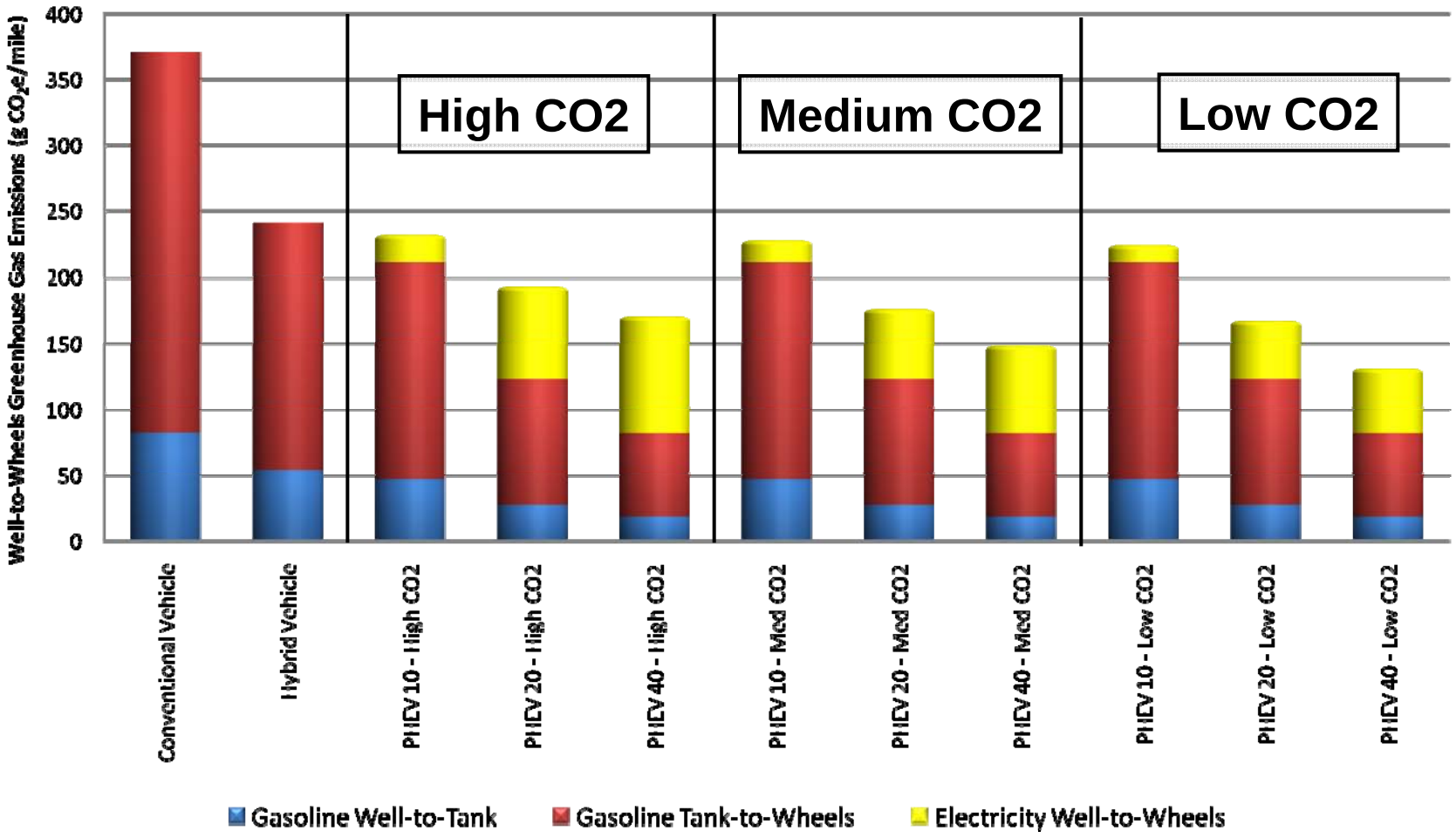
Electric Sector Simulation Results (2050)
PHEV 10, 20, & 40 – 12,000 Annual Miles



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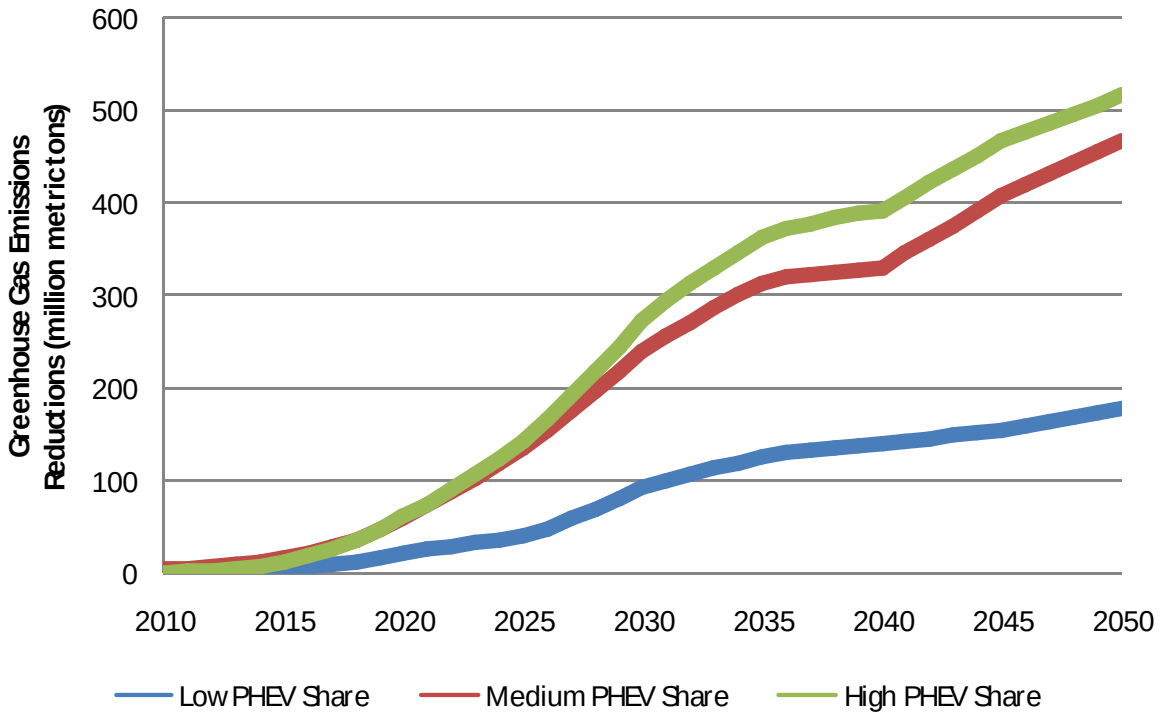
Greenhouse Gas Emissions Reductions

- Electricity grid evolves over time
- Nationwide fleet takes time to renew itself or “turn over”
- A potential 400-500 million metric ton annual reduction in GHG emissions (the US currently emits 6 million metric tons annually)



Annual Reduction in Greenhouse Gas Emissions From PHEV Adoption

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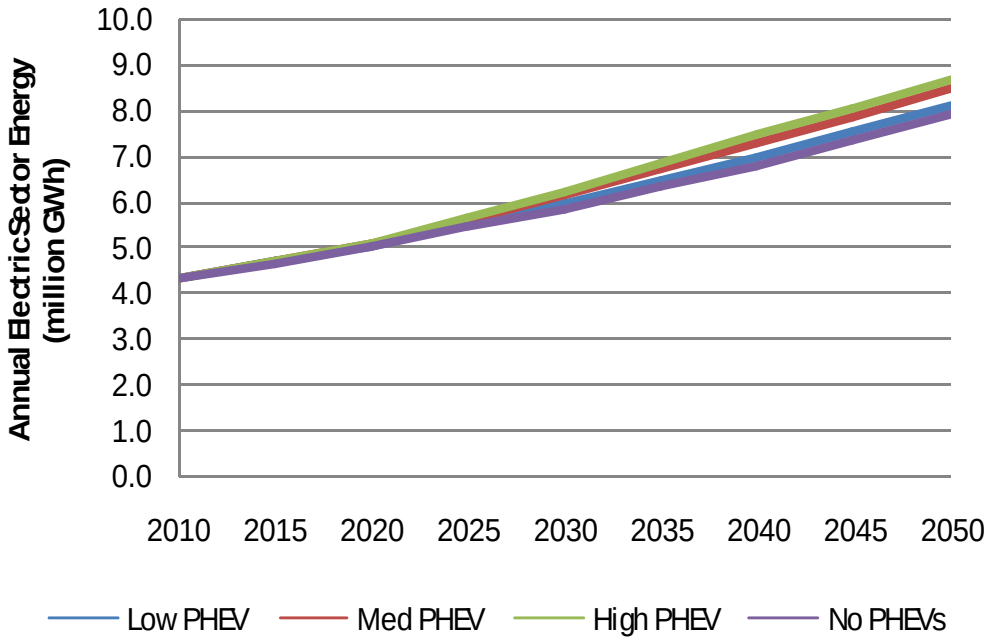
Impacts to Electricity and Petroleum

- Moderate electricity demand growth
- Capacity expansion 19 to 72 GW by 2050 nationwide (1.2 – 4.6%)
- 3-4 million barrels per day in oil savings (Medium PHEV Case, 2050)



Electricity Demand: Medium CO_2 Case

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Overall CO_2e Results

- All nine scenarios resulted in CO_2e reductions from PHEV adoption
- Every region of the country will see reductions
- In the future, PHEVs charged from new coal (highest emitter) w/o CCS roughly equivalent to HEV, superior to CV
  - There is unlikely to be a future electric scenario where PHEVs do not return CO_2e benefit

2050 Annual CO_2e Reduction (million metric tons)		**Electric Sector CO_2 Intensity**		
		High	Medium	Low
PHEV Fleet Penetration	Low	163	177	193
	Medium	394	468	478
	High	474	517	612

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Overview

CO_2 Results

Air Quality Results

Next Steps

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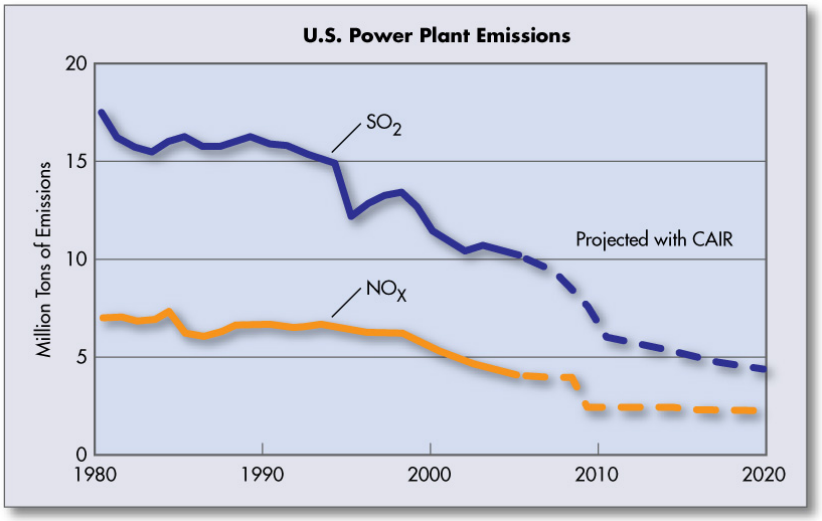
U.S. Power Plant Emissions Trends



Source: U.S. Environmental Protection Agency

- Power plant emissions of SO_2 and NOx will continue to decrease due to tighter federal regulatory limits (caps) on emissions
- Other local and national regulations further constrain power plant emissions
- Air quality is determined by emissions from all sources undergoing chemical reactions within the atmosphere

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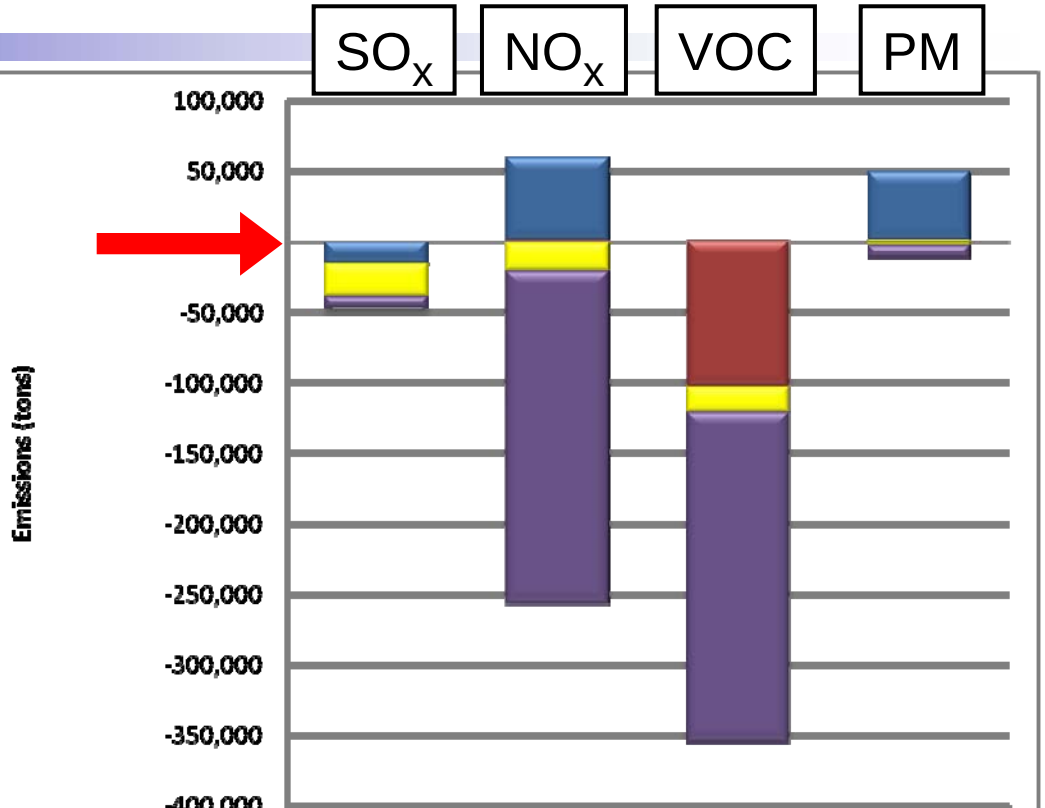
Net Changes in Criteria Emissions Due to PHEVs

Power Plant Emissions

- Emissions capped under law (SO_2, NOx, Hg) are essentially unchanged
- Primary PM emissions increase (defined by a performance standard)

Vehicle Emissions

- NOx, VOC, SO_2, PM all decrease
- Significant NOx, VOC reductions at vehicle tailpipe
- Reduction in refinery and related emissions



	SOx	NOx	VOC	PM
On-Road Vehicle	-7,716	-236,292	-234,342	-9,255
Refinery and Other Stationary	-23,549	-20,076	-17,804	-3,282
Distributed Upstream	0	-1,293	-103,323	-101
Power Plant	-16,284	58,916	0	49,434
	-47,549	-198,745	-355,469	36,796

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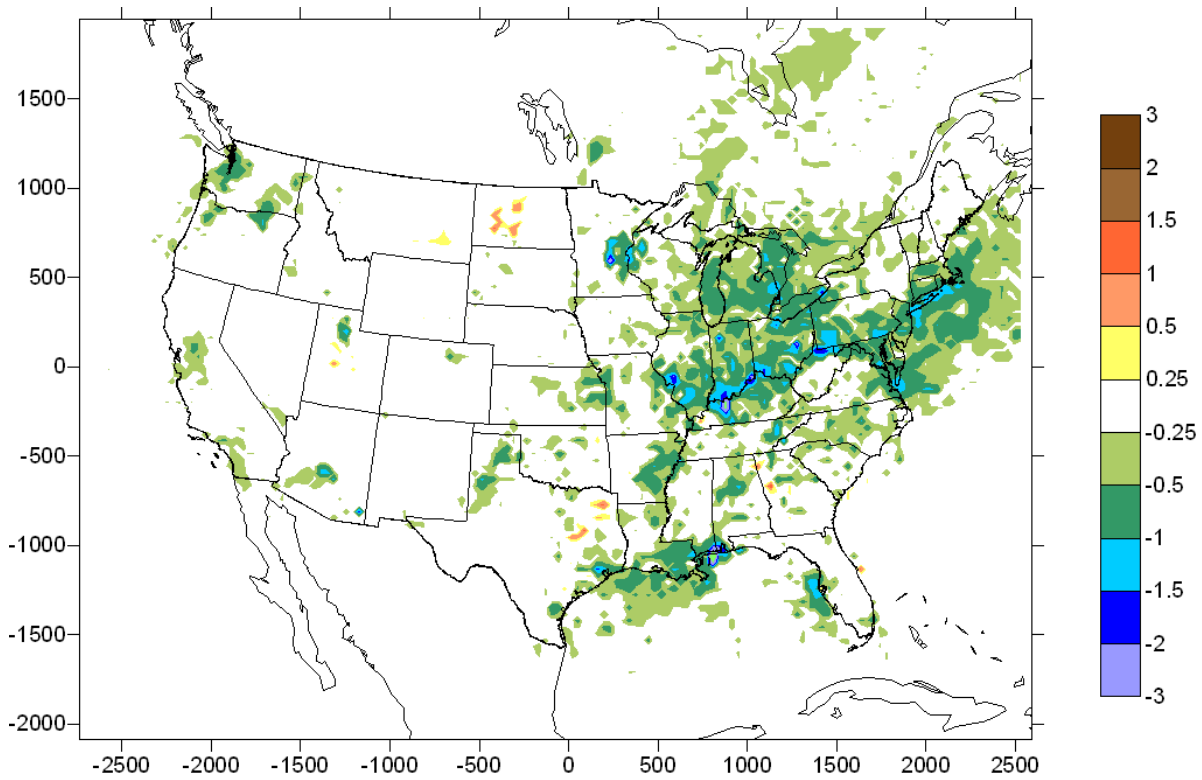
PHEVs Reduce Formation of Ozone

- Air quality model simulates atmospheric chemistry and transport
- Lower NOx and VOC emissions results in less ozone formation particularly in urban areas



Change in 8-Hour Ozone Design Value (ppb)
PHEV Case – Base Case

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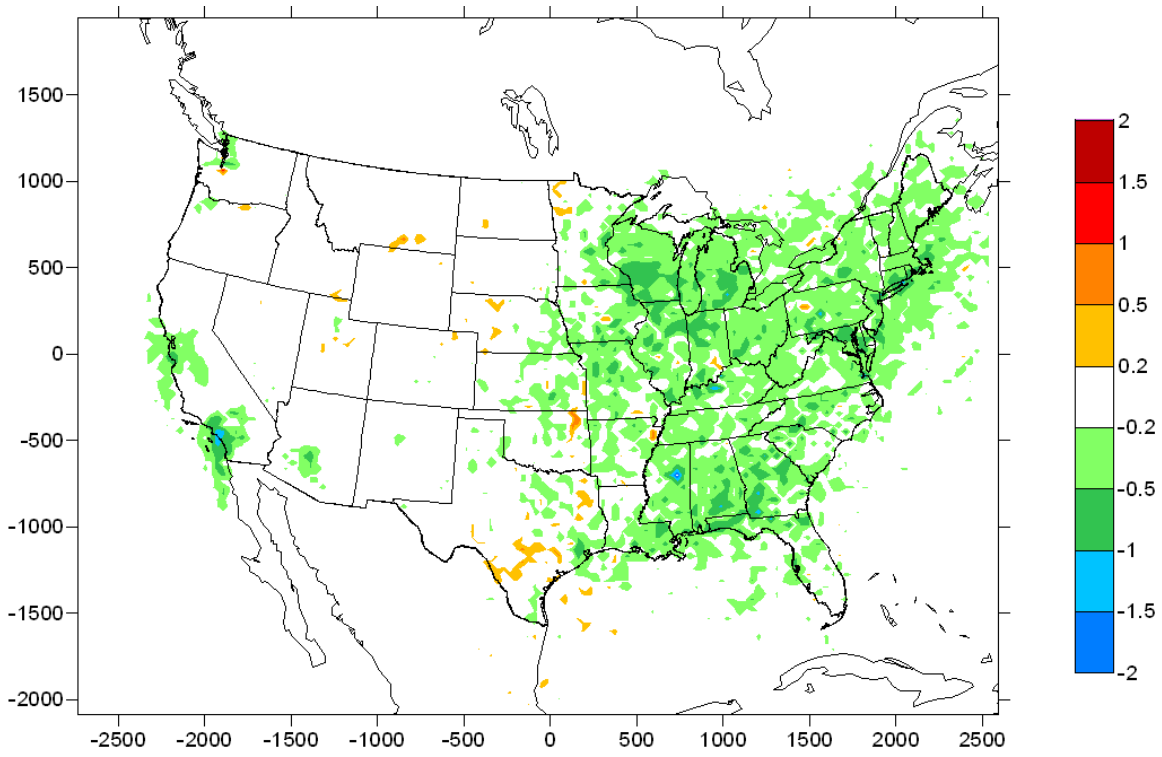
PHEVs Reduce Formation of Secondary $PM_{2.5}$

- $PM_{2.5}$ includes both direct emissions and secondary PM formed in the atmosphere
- PHEVs reduce motor vehicle emissions of VOC and NOx.
- VOCs emissions from power plants are not significant
- Total annual SO_2 and NOx from power plants capped by federal law
- The net result of PHEVs is a notable decrease in the formation of secondary $PM_{2.5}$



Change in Daily $PM_{2.5}$ Design Value (µg m^{-3})
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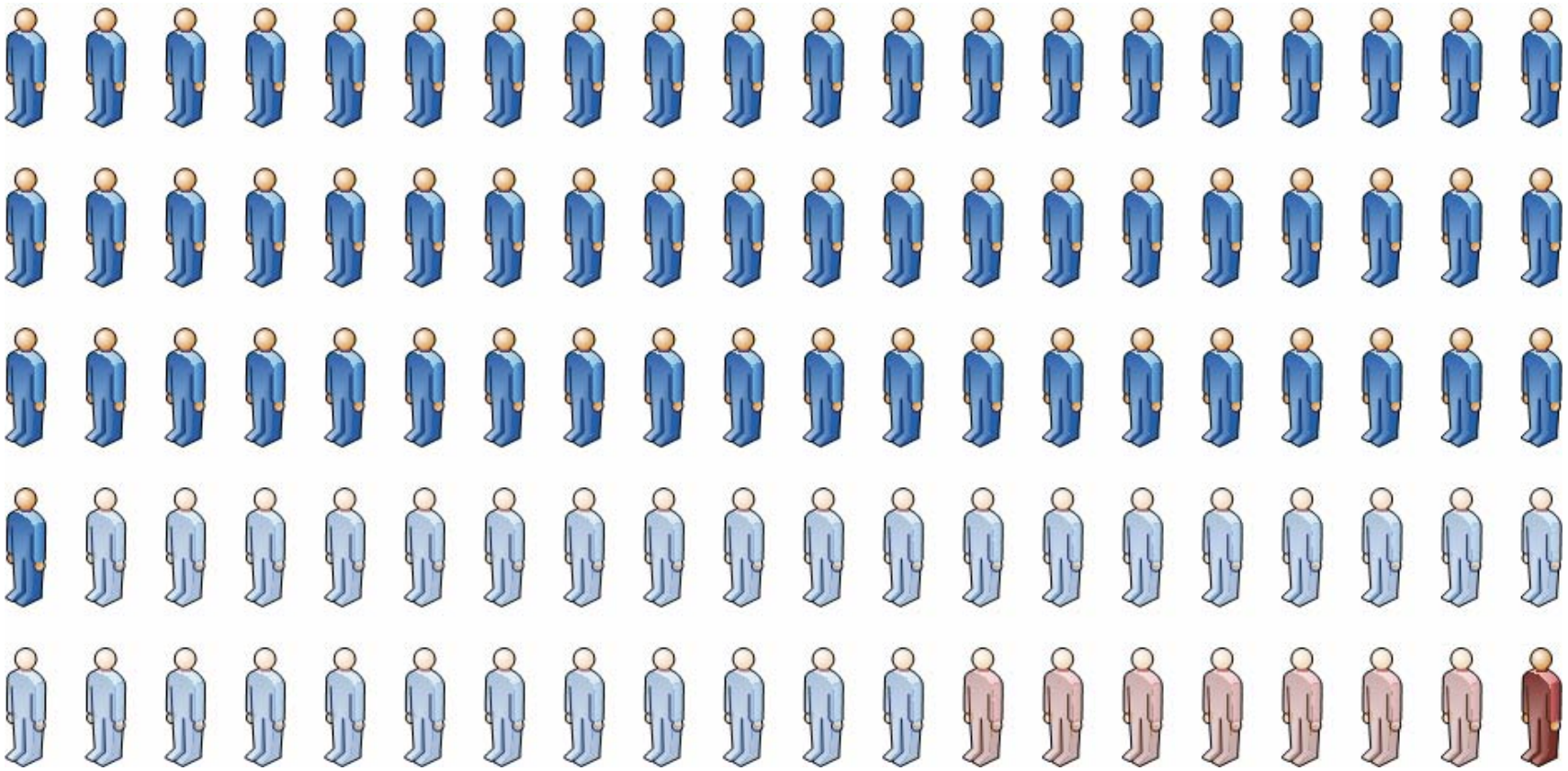
Ozone Design Value Exposure Changes



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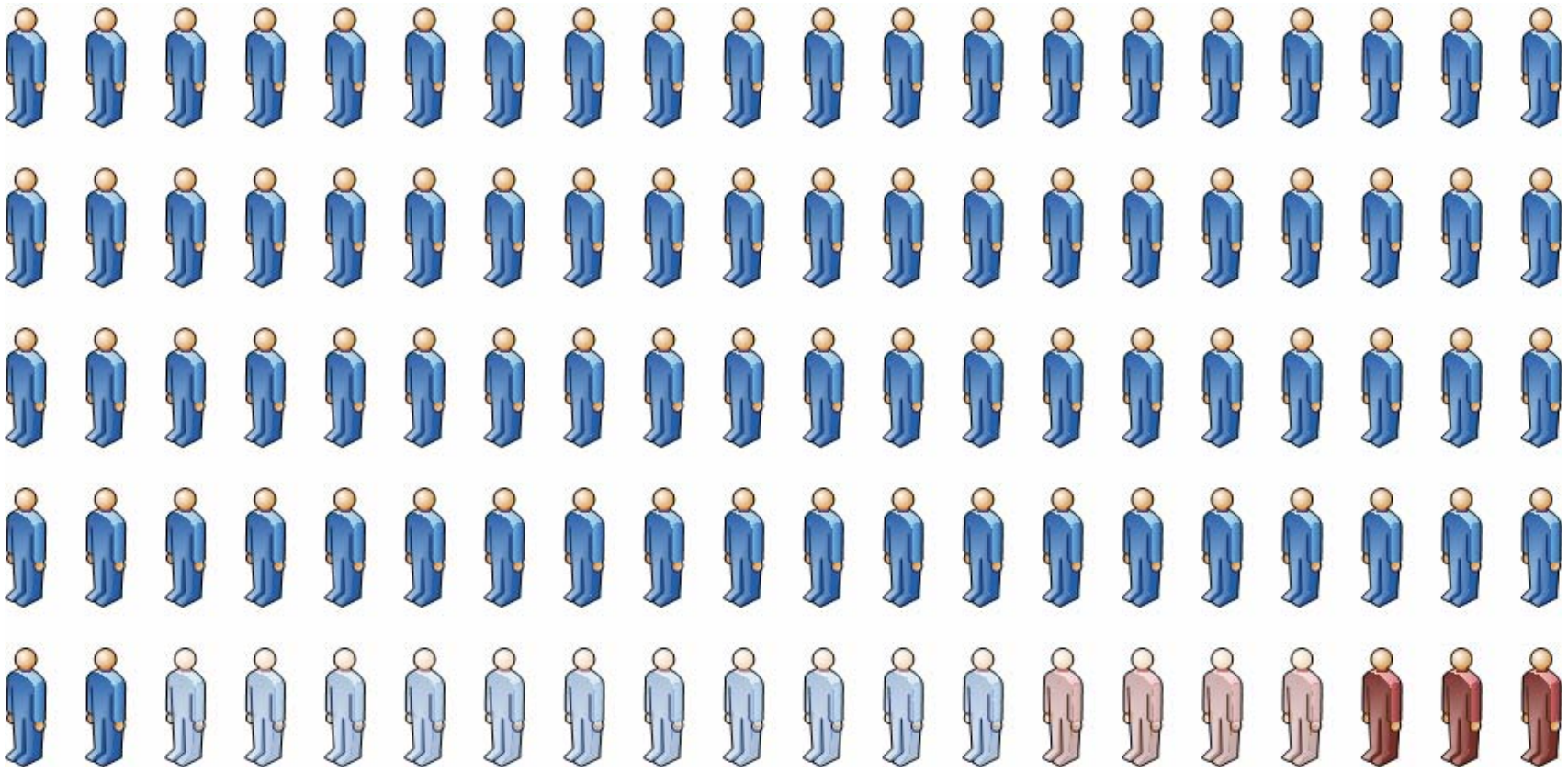
Daily $PM_{2.5}$ Design Value Exposure Changes



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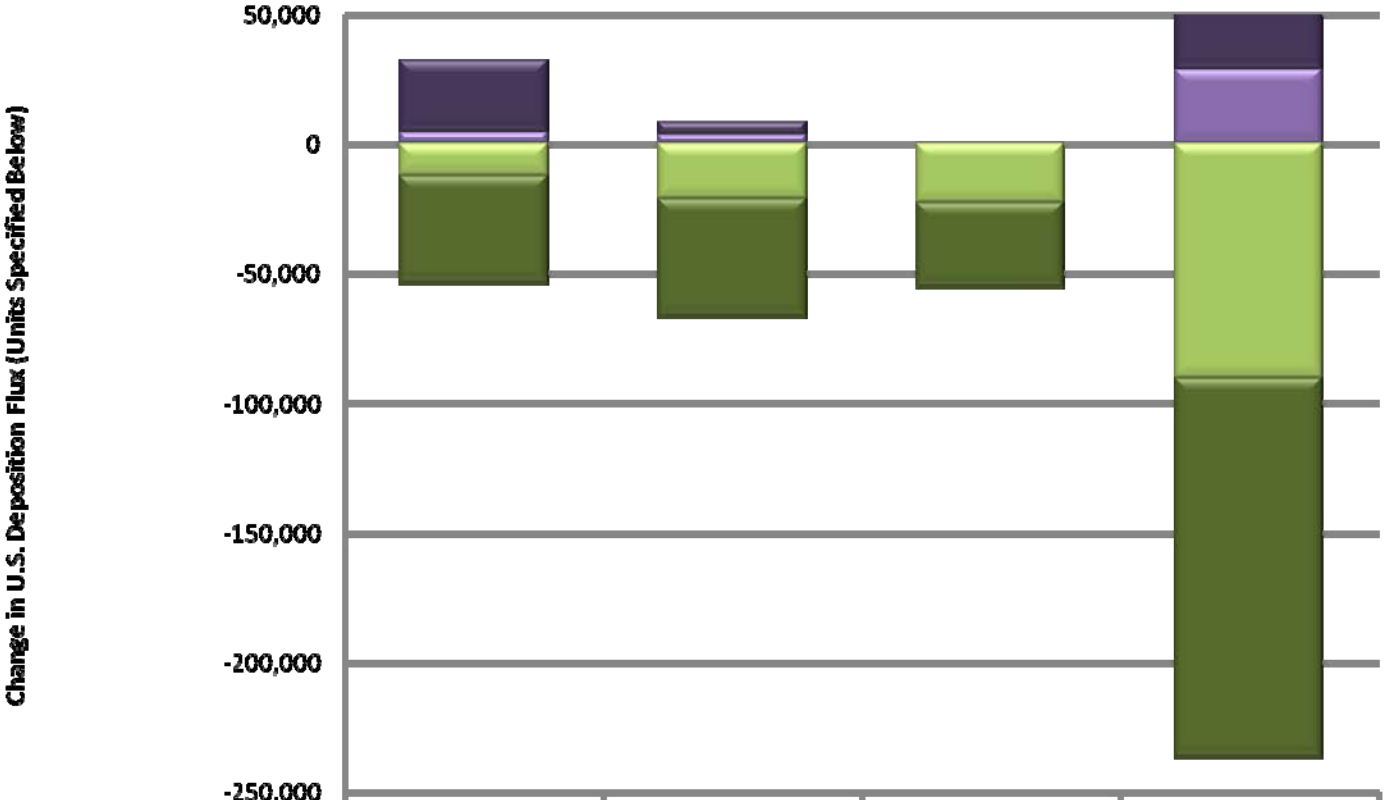
PHEVs Improve Overall Air Quality

Reduced Deposition of Sulfates, Nitrates, Nitrogen, Mercury



	Sulfate (ton)	Nitrate (ton)	Nitrogen (ton N)	Mercury (g)
Benefit above Threshold	-41,472	-45,490	-32,413	-146,370
Benefit below Threshold	-12,416	-20,995	-22,784	-90,202
Disbenefit above Threshold	27,769	4,973	233	48,377
Disbenefit below Threshold	4,562	3,396	233	28,693
	-26,114	-61,508	-54,963	-188,166

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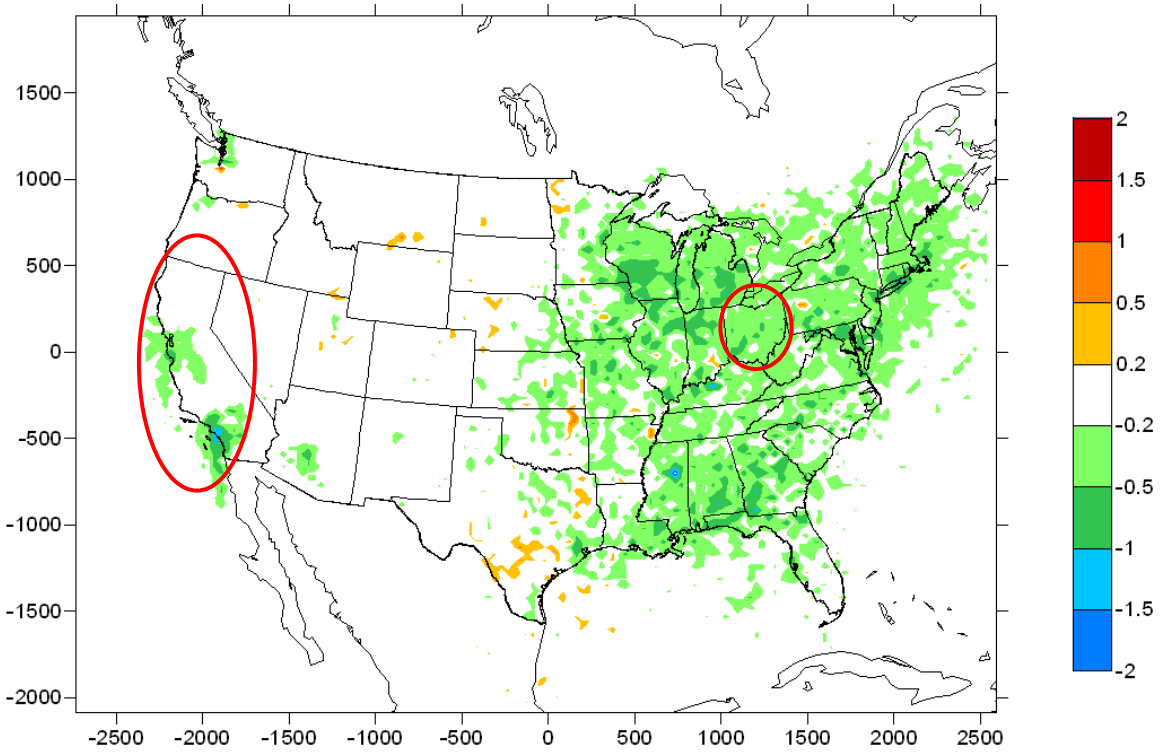
- Expand air quality analysis to include carbon constraints
- Continue GHG analysis as industry economics and technology changes
- Adopt market penetration forecasts in place of bounding scenarios
- Modify vehicle assumptions as PHEV technology evolves
- Expand analysis to other regions of interest



Change in Daily $PM_{2.5}$ Design Value (µg m^{-3})
PHEV Case – Base Case

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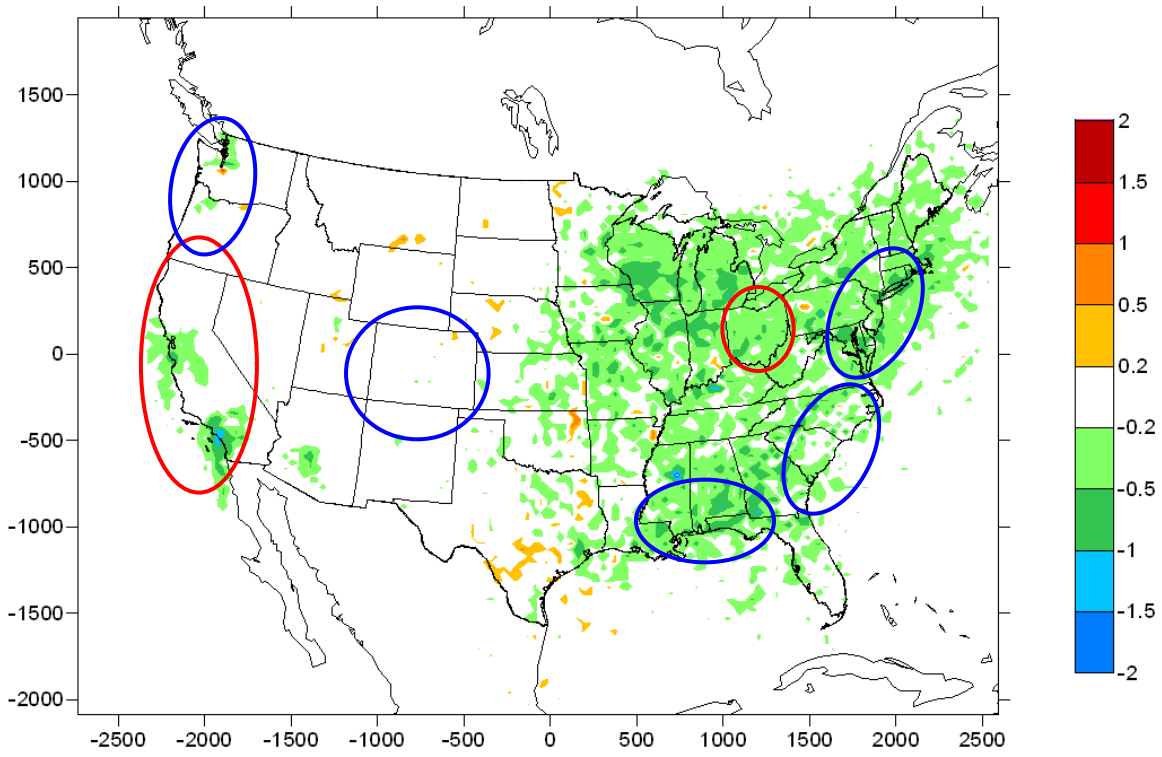

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